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Electricity is a cornerstone on which the economy and the daily lives of our nation's citizens depend. This essential commodity has no substitute. Unlike most commodities, electricity cannot easily be stored, so it must be produced at the same instant it is consumed. The electricity delivery system must be flexible enough, every second of the day and every day of the year, to accommodate the nation's ever changing demand for electricity. There is growing evidence that both private and public action are urgently needed to ensure our transmission system will continue to meet the nation's needs for reliable and affordable electricity in the 21st century.

Our National Transmission System Today and Tomorrow

The electricity transmission system is one of the greatest engineering achievements of the 20th century. It is an extensive system of interconnected networks in which high-voltage power lines transport electricity from generators to customers. A critical early decision to rely on alternating current (AC) technologies for high-voltage transmission has led to the construction of three major interconnected power systems: the Eastern and Western Interconnections, and the Electric Reliability Council of Texas (ERCOT). Within each system, disturbances or reliability events are felt nearly instantaneously throughout the system. This interdependence leads to reliance on well-coordinated actions among its users to ensure

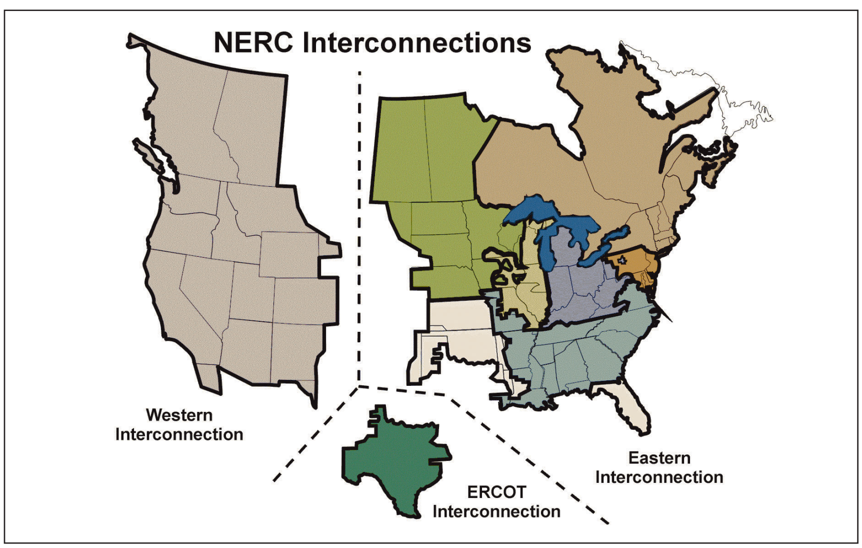


Fig. 1.1 North American Electricity Transmission Systems

The North American electricity transmission system consists of three interconnected systems: the Eastern Interconnection, the Western Interconnection, and most of the state of Texas. Within these interconnections, more than 140 control areas manage electricity operations for local areas and coordinate reliability through 10 regional councils.

Source: NERC 2001.

reliability. The continued need to coordinate actions to ensure reliability is a key institutional challenge as the system transitions to support competitive wholesale markets (see Section 4). There is also renewed interest in revisiting the decision to rely on AC transmission technologies and increasing reliance on direct current (DC) transmission technologies, which makes some coordination actions simpler in principle (see Sections 3 and 5).

The transmission system was built, over the past 100 years, by vertically integrated utilities that produced electricity at large generation stations located close to fuel supplies or needed infrastructure and then relied on transmission facilities to transport their electricity to customers. Interconnections among neighboring utility systems were constructed to exchange power to increase reliability and share excess generation during certain times of the year. Today, over 150,000 miles of high-voltage transmission lines link generators to load centers through interconnected transmission systems that span utility service territories, states, regions, and the borders of Mexico and Canada (Table 1.1).[3]

Ensuring the reliability of the transmission system has always been paramount. For years, utilities were the system's only users, and reliability was managed successfully through voluntary compliance with planning and operating standards established by the North American Electric Reliability Council (NERC). System operations depended on local utility expertise to complement these standards in recognition of the unique design of each utility's system and the technical complexity of coordinating operations.

Table 1.1

U.S. High-Voltage Transmission System

Voltage	Miles of Transmission Line
AC	
230 kV	76,762
345 kV	49,250
500 kV	26,038
765 kV	2,453
Total AC	154,503
DC	
250-300 kV	930
400 kV	852
450 kV	192
500 kV	1,333
Total DC	3,307
Total AC & DC	**157,810**

The U.S. electricity transmission system consists of over 150,000 miles of high-voltage transmission lines.

Source: NERC.

In 1996, the Federal Energy Regulatory Commission (FERC) issued its landmark Orders 888 and 889, which required utilities to allow non-utilities, or independent power producers, access to, and use of, utility transmission systems. Prior to these Orders, electricity production decisions were made centrally by vertically integrated utilities relying on generators they owned or exchanges with neighboring utilities. Investment in new generation by utilities had slowed and production of electricity by non-utilities was modest. FERC's orders were fundamental shifts in electricity policy and dramatically changed the ways that electricity production decisions were made and, consequently, in how the transmission system is used and operated.

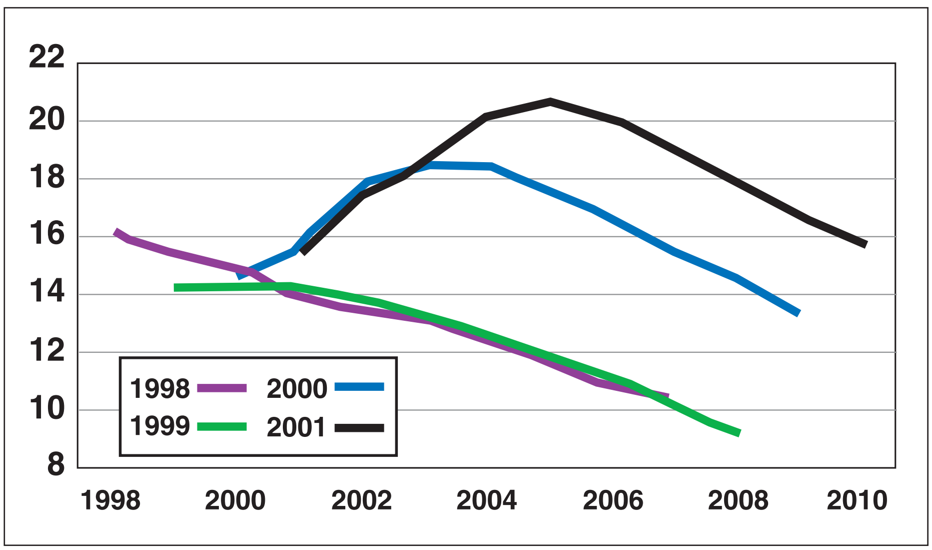
[3]Electricity is delivered from the high-voltage transmission system to customers through progressively lower voltage (<100 kV) distribution systems.

Centralized decision making by vertically integrated utilities, alone, now no longer determines electricity production. Instead, competitive market forces, involving a number of new market participants, increasingly determine who produces electricity and where it will be consumed. Since 1996, the transmission system has been slowly transformed into an interstate highway of commerce upon which emerging wholesale electricity markets depend.

During the past few years, wholesale power markets have flourished, as new market participants have undertaken the risks and rewards of developing merchant power plants. From 1996 to 1999, wholesale power marketers increased sales by more than six-fold. This, in addition to both continued load growth and increased wholesale power sales by traditional utilities, has resulted in the need for an expanded transmission system. More than half of all electricity generated is now exchanged on the wholesale market before being sold to ultimate consumers.[4]

The creation of wholesale electricity markets has enabled new market participants to address the nation's needs for new generating capacity. After years of decline, NERC forecasts now indicate that generation capacity margins will increase.[5,6] Summer peak electricity demand and generation capacity are projected to increase by almost 20 percent each during the next 10 years. Much of this new generation will be developed by independent power producers and unregulated affiliates of utilities.[7] (Figure 1.2)

Fig. 1.2
Capacity Margins over Time



After many years of decline, the ratio of generating capacity to electricity demand has begun and, according to NERC forecasts, will continue to increase. This increase means that there will be adequate generation capacity to meet expected electricity demand.

Source: NERC. 2001. *Reliability Assessment, 2001-2010.* Download from http://www.nerc.com

[4]U.S. Energy Information Administration. 2000. *The Restructuring of the Electric Power Industry: A Capsule of Issues and Events.* Download from http://www.eia.doe.gov

[5]Capacity margin is the ratio of generating capacity to electricity demand. Excess generating capacity is needed to ensure reliability because demand can shift rapidly (e.g., in response to weather) and total generation capacity is not available at all times (e.g., because of planned maintenance or unexpected equipment failure).

[6]North American Electric Reliability Council. 2001. *Reliability Assessment, 2001-2010*. Download from http://www.nerc.com

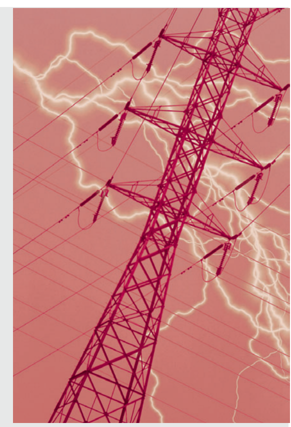
[7]However, the recent contraction of our capital markets, and the announced delay in the construction of many new power plants, will affect this trend.

The U.S. Electricity Transmission System Is Under Stress

Despite the success of the wholesale electricity markets and the ability of new participants to address the nation's needs for new generation capacity, there is growing evidence that the U.S. transmission system is under stress. Growth in electricity demand and new generation, lack of investment in new transmission facilities, and the incomplete transition to fully efficient and competitive wholesale markets have allowed transmission bottlenecks to emerge. These bottlenecks increase electricity costs to consumers and increase the risks of blackouts.

The growth of electricity demand during the 1990s, coupled with new generation resulting from the emergence of competitive wholesale electricity markets, has led to electricity flows that are greater in size and in different directions than those that were

The California Electricity Crisis



At its root, the California power crisis was caused by an imbalance in the supply and demand for electricity. Very little new generating capacity had been built or proposed in California and the western states during the early 1990s. Once electricity restructuring rules were put in place, independent power producers responded quickly, beginning in 1997, to file applications to build more than 14,000 megawatts of new capacity. Yet, almost none of this proposed new capacity was available by summer 2000. Despite electricity demand growth rates that were lower than the national average during the 1990s, California was short of generation capacity. The absence of new generation capacity, along with high natural gas prices, lack of water available for hydro-electric generation, market design flaws, and little demand-side participation in the energy market all combined to drive wholesale power prices up to unprecedented levels.

The lack of adequate transmission played an important role in exacerbating the problems created by the imbalance between California's supply and demand for electricity. Because transmission is constrained between the northern and southern portions of the state, the number of competitors able to provide electricity in each of these markets is effectively reduced thereby leading to higher prices.

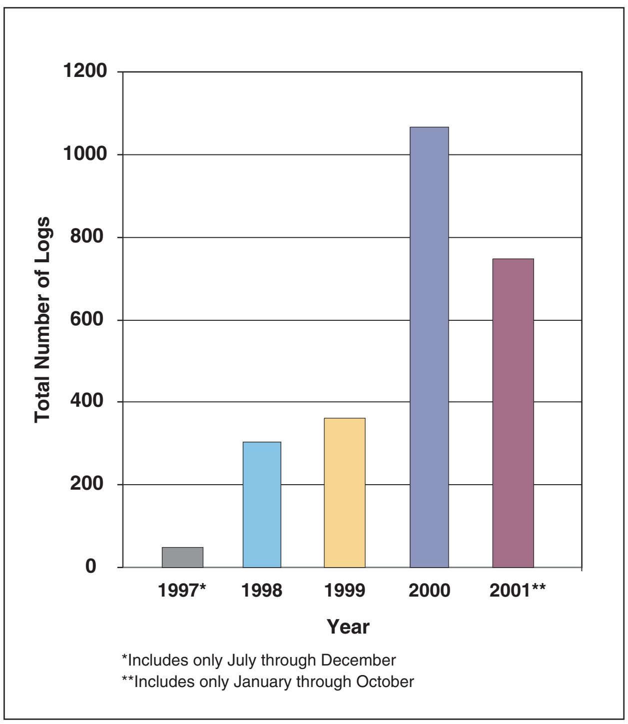
The situation in California stabilized during the past year when wholesale power prices fell dramatically as a result of lower natural gas prices, new generation finally coming on line, extraordinary load reduction efforts by households and businesses, improved hydro conditions, and Federal Energy Regulatory Commission actions. Nevertheless, transmission system upgrades remain an important element of a comprehensive, long-term solution to California's electricity system.

Source: U.S. Department of Energy. 2000. *Horizontal Market Power in Restructured Electricity Markets*. DOE/PO-0060. Download from http://www.policy.energy.gov/HMPReport.pdf anticipated when the transmission system was first designed. NERC reports that there is minimal operating experience for handling these conditions. The increased use of the system has led to transmission congestion and less operating flexibility to respond to system problems or component failures. This lack of flexibility has increased the risk of blackouts. Today, power failures, close calls, and near misses are much more common than in the past.

Transmission congestion or bottlenecks result when there is not enough transmission capability to accommodate all requests to ship power over existing lines and maintain adequate safety margins for reliability. Because electricity cannot yet be stored economically, transmission system operators must deny requests for transmission service when they receive too many of them in order to prevent lines from becoming overloaded. In other words, transmission congestion does not refer to deliveries that are merely held up or delayed (as in traffic congestion); it refers to transactions that cannot be executed.

Transmission operators manage transmission congestion through a set of NERC-approved procedures called Available Transfer Capability (ATC) and Transmission Loading Relief (TLR). ATC calculations establish the maximum ability of a system to support expected wholesale transactions reliably. When the system is in danger of exceeding these limits, TLR procedures (known as TLR "calls") determine which requests for transmission will be denied in order to prevent lines from becoming overloaded.

Fig. 1.3
Transmission Loading Relief Events



Actions by operators to curtail proposed transactions in order to ensure reliability according to procedures developed by the North American Electric Reliability Council have increased dramatically since the time they were first adopted in 1997.

Source: NERC.

In the last two years, the frequency of TLR "calls" has increased dramatically. The frequent use of TLRs indicates that the system is under greater stress because it is being operated closer to its limits. (Figure 1.3)

Today, the ATC and TLR procedures play a key role in ensuring transmission reliability. Unfortunately, the use of these procedures also interferes with market efficiency. Transmission congestion and the use of TLR calls increases consumer costs by frequently denying low-cost transactions in favor of high-cost transactions. As customer demand in an area surpasses the import capability of the transmission lines serving that area, operators are forced to meet the area's energy demand with more expensive local generation rather than less expensive generation from elsewhere in the region.[8]

Construction of new transmission facilities would alleviate these stresses. However, NERC also reports that investment in new transmission facilities is lagging far behind investment in new generation and growth in electricity demand. Construction of high-voltage transmission facilities is expected to increase by only 6 percent (in line-miles) during the next 10 years, in contrast to the expected 20 percent increase in electricity demand and generation capacity (in MW). Although we would not expect transmission to grow as quickly as new generation capacity or demand, this projected growth is not adequate to ensure reliability and sustain continued growth of competitive regional wholesale electricity markets. (Figure 1.4)

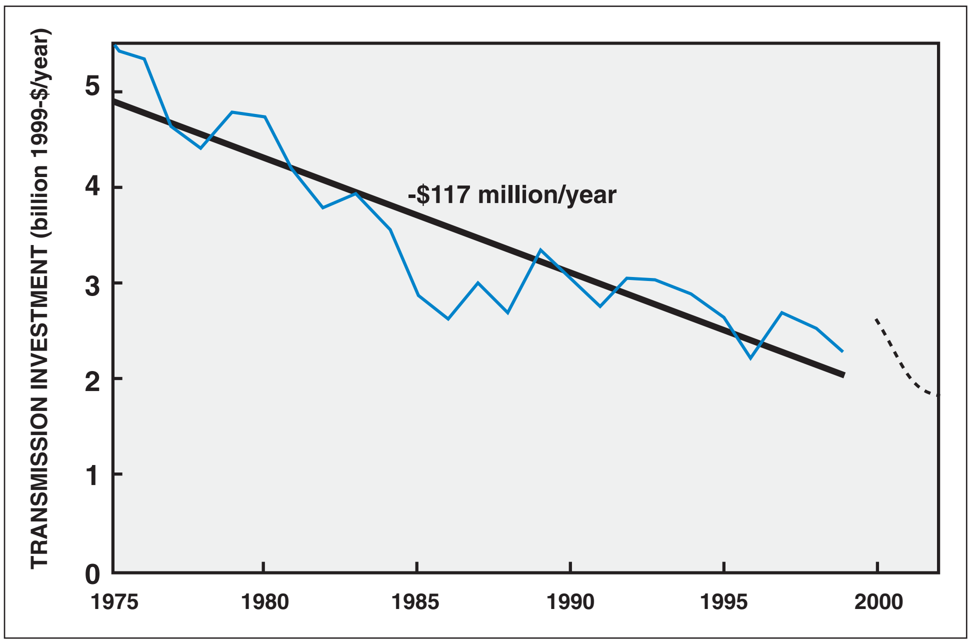


Fig. 1.4 **Transmission System Investment over Time**

Investment in new transmission facilities has declined steadily for the last 25 years.

Source: E. Hirst and B. Kirby. 2001. *Transmission Planning for a Restructured U.S. Electricity Industry.* Edison Electric Institute.

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Toward the Transmission System of Tomorrow

During the late 1970s, there was debate about whether the U.S. should "nationalize" the electricity grid. Some felt the electricity system was of such great importance that it had to be managed by the federal government; others were wary of centralized federal decision making and advocated industry-led solutions. During the 1990s, the nation chose to introduce competi-

[8]For additional background, see the Issue Paper, *Transmission System Operation and Interconnection,* by F. Alvarado and S. Oren.

tion to the electricity market and has since begun to reap the benefits of private developers' investment in merchant generation capacity. A key benefit to consumers is that the financial risks of power plant construction and operation have been shifted from consumers to private developers whose earnings depend on their ability to generate power competitively.

Robust and reliable regional electricity transmission systems are the key to sustaining fair and efficient competition in wholesale markets that lowers costs to consumers. The national transmission grid DOE envisions is based on the principles of free markets with clear rules, equal access, consumer safeguards, economic incentives, and investment opportunities rather than federal ownership and operation.

Building new transmission facilities or undertaking other strategies to address transmission bottlenecks should depend first and foremost on market participants responding to business opportunities. Similarly, greater electrical interconnections among existing transmissions systems should be the result of regional initiatives, not federal directives. When the private sector and markets can do the job, the federal role is to let regional markets work.

Discussions of regional transmission systems heighten state concerns over their regulatory responsibility to protect reliability and ensure affordable electricity to retail consumers. Movement toward regional transmission systems and competitive wholesale electricity markets must balance state, regional, and federal responsibilities. In the end, consumers must be assured reliable and affordable electricity.

The future provision of reliable and affordable electricity requires modernizing the structure and operation of the nation's transmission systems to serve the regional needs of competitive wholesale electricity markets. The transmission systems of tomorrow must be operated in ways that take full advantage of market forces to ensure reliability in an economically efficient manner, allow customers to adjust their demands in response to system needs and be compensated for these actions, incorporate advanced hardware and software technologies to increase utilization of existing facilities safely, and follow strict rules for reliability with appropriate penalties for non-compliance. The transmission systems of tomorrow must be built by relying on open regional planning processes that consider a wide range of alternatives, accelerating the siting and permitting of needed facilities, taking full advantage of advanced transmission technologies, and incorporating appropriate safeguards to ensure the physical and cyber security of the system.

The cost of transmission accounts for less than 10 percent of the final delivered cost of electricity in what is today a $224 billion electricity industry.[9] We cannot afford to allow the relatively small cost of transmission to prevent consumers from enjoying the reliable and affordable electricity service that properly managed competitive forces will deliver to our nation.

[9]Source: Energy Information Administration. *Electric Sales and Revenue 2000.* Download from http://www.eia.doe.gov